

Field efficacy of combinations of attractants for bark beetles and longicorn beetles in trapping wood-boring beetles

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Abstract: *Monochamus alternatus* Hope is the primary vector for spreading pine wilt disease. Use of attractants in the control of *M. alternatus* population is effective and pollution-free. In this study, the field test was conducted to evaluate the attractiveness of *M. alternatus* attractant combined with six kinds of bark beetle attractants to *M. alternatus* adults. The results showed that there was no significant difference among the combinations of each of bark beetle attractants for *Tomicus minor* Hartig (3-carene-10-ol), *Ips typographus* Linnaeus (2-methyl-3-buten-2-ol), *Scolytus multistriatus* Marsham (4-methyl-3-heptanol), and *T. piniperda* Linnaeus (verbenol) with *M. alternatus* attractant ($P < 0.05$). The combinations of attractants for either *Dendroctonus brevicomis* LeConte (exo-brevicomine) or *D. pseudotsugae* (1-methylcyclohex-2-en-1-ol) with *M. alternatus* attractant were less attractive to *M. alternatus*. Compared with *M. alternatus* attractant used only, the combination of either *D. brevicomis* or *D. pseudotsugae* with *M. alternatus* attractant was also less attractive as indicated by the species and number of wood-boring beetle individuals captured.

Key words: *Monochamus alternatus*; bark beetles; attractant; trapping; wood-boring beetles

1 INTRODUCTION

Monochamus alternatus Hope is a main vector for pinewood nematode, the causal agent for the destructive pine wilt disease. The control and treatment of *M. alternatus* is difficult because of its good hiding ability and thus inaccessibility to chemical agents and natural enemies. As one efficient way to control pest population, trapping *M. alternatus* with an attractant is useful in the treatment of the harmful species with no detriment to the environment. This method has been widely utilized in the comprehensive management of various pests (Lin *et al.*, 2010). In recent years, researchers around the world have developed a variety of attractants from volatile substances of plants. Many inducers have also been successfully developed to produce particular effects on monitoring and controlling *M. alternatus* as well as inhibiting the spread of pine wilt disease and breaking the infection cycle (Kobayashi *et al.*, 1984; Tang *et al.*, 2000; Zhao *et al.*, 2001; Hao *et al.*, 2009). Previous experimental results demonstrated that some bark beetle attractants were attractive to several longicorn

beetles in Europe and North America (Billings and Cameron, 1984; Raffa, 1991; Pajares *et al.*, 2004; Miller and Asaro, 2005; Miller and Rabaglia, 2009). However, recent field tests in China showed that two bark beetle attractants had a negative attractiveness to *M. alternatus* (Fan *et al.*, 2010). Therefore, this study was designed to screen and optimize the more effective substances of *M. alternatus* attractants to enhance their utility. A novel field test was carried out to investigate the attractiveness to *M. alternatus* of six bark beetle attractants combined with a Chinese longicorn beetle attractant. The results will provide a basis for monitoring and controlling *M. alternatus* and for inhibiting the spread of pine wilt disease.

2 MATERIAL AND METHODS

2.1 Experimental site

The study was conducted in the forest at Fuyang, Zhejiang Province, China (30°03'N, 119°57'E). The dominant species in the forest was *Pinus massoniana*, *P. elliotii* and *P. taeda*. The pine trees on the experiment site had a 20%–30% of infection rate of the pine wood nematode disease, but the site

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had not been treated with chemical pesticides for a long time. For *P. massoniana* in the experimental site, it has an area of 301 hm², an average age of 23 years, an average height of 6 m and an average density of 800 trees/hm².

2.2 Attractants

All of the attractants used in this experiment are

listed in the Table 1. *M. alternatus* attractant M-99 was provided by the Forest Pest Control and Quarantine Bureau of Zhejiang Province, China, and bark beetle attractants were provided by the French National Institute for Agricultural Research, France (INRA).

Table 1 Chemical lures and enantiomeric purity of chemicals tested in the field assay

Lure code	Compounds	Target or attracted species	Formula	Chemical purity (%)	Enantiomeric ratio (+ : -)	Release rate at 24 – 26℃
A	3-Carene-10-ol	<i>Tomicus minor</i>	C ₁₀ H ₁₆ O	91	90:10	10 mg/d
B	2-Methyl-3-buten-2-ol	<i>Ips typographus</i>	C ₅ H ₁₀ O	98	99.5:0.5	36 mg/d
C	4-Methyl-3-heptanol	<i>Scolytus multistriatus</i>	C ₈ H ₁₈ O	99	88:12	0.7 mg/d
D	Verbenol	<i>Tomicus piniperda</i>	C ₁₀ H ₁₆ O	98	65:35	3.5 mg/d
E	Exo-brevicommin	<i>Dendroctonus brevicomis</i>	C ₉ H ₁₆ O ₂	98	83:17	0.6 mg/d
F	1-Methylcyclohex-2-en-1-ol	<i>Dendroctonus pseudotsugae</i>	C ₇ H ₁₂ O	95	65:35	1.2 mg/d
M-99	M-99	<i>Monochamus alternatus</i>	C ₁₀ H ₁₆ , C ₂ H ₄ O, C ₃ H ₆ O	–	–	10 mL/d

M-99 attractant is from Forest Pest Control and Quarantine Bureau of Zhejiang Province; the release rates were based on the protocols provided by the manufacturers.

2.3 Experimental design

The experiment was carried out from May 1 to September 7, 2010, which includes pre- and post-peaks of *M. alternatus* adult emergence. Pine trees with a distance of 3 m or more between each other and located on the roadside, hillside and ridge, where air circulation was good, were selected. The cross vanes type traps were used for beetle collection. Traps were fixed with iron wire on the trees and 1.5 – 2.0 m above the ground and at least 50 m apart from each other.

The experiment consisted of 7 treatments (Table 2), each with 5 replications. When a trap was set, the attractants were fixed in the middle of the column inside the trap without a cap or with an opening in the sack for slow release of volatile compounds. M-99 was replaced every 15 days and the rest had no replacement. All insects trapped were collected and recorded every 3 – 7 days depending on weather conditions. After each collection, positions were switched for neighboring traps. The insects captured were taken back to the laboratory for counting and identification. Meanwhile, the number of *M. alternatus* adults, eggs and nematodes carried were observed with microscopes and statistically calculated.

2.4 Statistical analysis

Statistic analysis of the experimental data was performed using Microsoft Office Excel 2007. One way ANOVA in SPSS13.0 was performed for the

attractive effects between different lures. In addition, Duncan's method was used to analyze the differences between various treatments ($P < 0.05$).

3 RESULTS AND ANALYSIS

3.1 Attractiveness of different lures to *M. alternatus*

A total of 922 *M. alternatus* adults (478 males and 444 females; sex ratio of 1.08) were captured by the seven attractants from May 1st to September 7th. The attractiveness of M-99, A + M-99, B + M-99, C + M-99, D + M-99, E + M-99, and F + M-99 to *M. alternatus* is detailed in Table 2.

Analysis of variance revealed that the attractiveness of M-99, A + M-99, B + M-99, C + M-99, and D + M-99 was not significantly different, but it was significantly higher than that of E + M-99 and F + M-99 (Table 2). The average individual number of *M. alternatus* adults trapped by E + M-99 and F + M-99 was 13.0 and 16.8, respectively, indicating that these combinations of chemicals were less attractive to *M. alternatus*.

3.2 Quantities of captured *M. alternatus* adult-carried nematodes and female-carried eggs

Microscopic examination of *M. alternatus* adults trapped by the seven attractants revealed that the percentages of adults carrying pine wood nematodes trapped by M-99, A + M-99, B + M-99, C + M-99, D + M-99, E + M-99, and F + M-99 were 75%, 85%, 72%, 63%, 68%, 42%, and 56%,

respectively. The adult females trapped by the seven attractants all had deep yellow mature eggs and white immature eggs in their ovaries. As shown in Table 2, the number of eggs per females trapped in different treatments had no significant difference.

3.3 Attractiveness of different attractant combinations to other wood-boring beetles

The species and number of other wood-boring

beetles trapped by M-99 and six attractant combinations are listed in Table 3. Other boring beetles trapped included 21 species in 9 families, including 8 species of Cerambycidae, 3 species of Elateridae, 2 species of Melolonthidae, 2 species of Tenebrionidae, 3 species of Curculionidae, 1 species of Scolytidae, 1 species of Buprestidae, and 1 species of Cleridae.

Table 2 The attractive effect of different treatments to *Monochamus alternatus* in the forest

Lure combination	Total number of individuals attracted	Sex ratio (♂ / ♀)	Average number/trap	Number of nematodes	Number of eggs per individual
M-99	185	90/79	39.0 ± 2.5 a	4 810	10.2
A + M-99	196	98/98	41.8 ± 5.4 a	3 560	11.9
B + M-99	153	72/73	37.8 ± 2.9 a	1 890	10.5
C + M-99	119	58/61	27.2 ± 7.1 ab	2 500	10.2
D + M-99	177	95/82	36.8 ± 2.4 a	4 540	9.1
E + M-99	57	30/27	13.0 ± 1.7 b	1 010	10.3
F + M-99	68	35/24	16.8 ± 2.8 b	4 200	10.9

The differences between various treatments were analyzed by the Duncan's method ($P < 0.05$). Data (mean ± SD) in the same column with different letters are significantly different. A: 3-Carene-10-ol; B: 2-Methyl-3-buten-2-ol; C: 4-Methyl-3-heptanol; D: Verbenol; E: Exo-brevicomin; F: 1-Methylcyclohex-2-en-1-ol. The same below.

Table 3 The species and number of individuals of wood-boring insects trapped by different attractants

Family	Species	Total number of individuals attracted						
		M-99	A + M-99	B + M-99	C + M-99	D + M-99	E + M-99	F + M-99
Cerambycidae	<i>Ureacha angusta</i>	84	17	45	36	25	46	42
	<i>Purpuricenus temminckii</i>	4	0	3	1	2	2	3
	<i>Spondylis buprestoides</i>	2	12	17	14	22	22	6
	<i>Allotraeus grahami</i>	2	0	2	0	0	0	2
	<i>Chlorophorus annularis</i>	1	0	2	2	0	7	3
	<i>Niphona furcata</i>	4	1	0	0	1	0	2
Elateridae	<i>Camposternus elongatus</i>	2	1	0	0	0	0	0
	<i>Cryptalaus larvatus</i>	6	7	3	6	7	9	4
	<i>Agrypnus bipapulatus</i>	6	1	5	8	4	9	4
Melolonthidae	<i>Holotrichia parallela</i>	7	0	3	0	2	4	4
	<i>Metabolanus tumidifrons</i>	0	0	4	7	0	5	0
Tenebrionidae	<i>Plesiophthalmus</i> sp.	5	0	5	3	1	0	4
	<i>Derosphaerus foveolatus</i>	6	0	0	0	1	0	5
Curculionidae	<i>Shirahoshizo patruelis</i>	2	0	2	2	4	4	6
	<i>Shirahoshizo erectus</i>	2	1	0	1	1	1	0
	<i>Hyposipalus gigas</i>	0	1	3	7	3	6	2
Scolytidae	<i>Cryphalus massonianus</i>	2	0	0	0	0	0	0
Buprestidae	<i>Chalcophora japonica</i>	0	0	0	1	0	1	0
Cleridae	<i>Tillus notatus</i>	7	3	3	12	1	0	7

It was revealed that the number of *Ureacha angusta* (Pascoe) trapped was largest, accounting for 37% of the total, with an average of 59 captured per trap, respectively. As compared with M-99 alone, combinations of M-99 and different bark beetle attractants had different attractive effects with regard to the number of wood-boring beetles and the species trapped. Specifically, attractant combinations were less attractive to *U. angusta* while significantly more attractive to *S. buprestoides* than M-99.

4 DISCUSSION

This study showed that the combinations of M-99 and each bark beetle attractants were less effective compared with M-99 alone in terms of the number of individuals and species captured. There was no significant difference in the number of individuals and species captured among M-99, A + M-99, B + M-99, and D + M-99, indicating that adding 3-carene-10-ol, 2-methyl-3-buten-2-ol, verbenol had no enhanced or inhibitory effect on M-99, whereas the attractiveness of E + M-99 and F + M-99 was significantly lower than that of M-99 used alone, indicating that exo-brevicomin and 1-methylcyclohex-2-en-1-ol inhibited the attractive effect of M-99 to *M. alternatus*.

Fan *et al.* (2010) demonstrated that the bark beetle pheromone components, ipsdienol and ipsenol, decreased catches of *M. alternatus* in traps baited with ethanol and (+)- α -pinene, similar to the result of exo-brevicomin and 1-methylcyclohex-2-en-1-ol in this study. This may be related to composition and ratio of the attractants, as well as the chemical interaction of the volatile substances in the attractant combinations. *M. alternatus* attractant, M-99, is mainly composed of ethanol, α -pinene, aldehydes and ketones, which might reduce the attractiveness to *M. alternatus* when combined with bark beetle attractants.

Based on the species of major pine boring pests trapped in this study, we hypothesize that trapping by M-99 or by M-99 combined with one of the bark beetle attractants, 3-carene-10-ol, 2-methyl-3-buten-2-ol, or verbenol, may effectively reduce *M. alternatus* population density, and consequently provide effective

control of the occurrence and spread of pine wilt disease. Moreover, it will also reduce the population density of other major pine boring pests, such as *Ureacha angusta* and *Spondylis buprestoides*, thereby reducing their potential hazards to pine forests.

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不同小蠹类与天牛类引诱剂联用对蛀干甲虫的林间诱捕效果

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摘要: 松墨天牛 *Monochamus alternatus* Hope 是传播松材线虫病的主要媒介, 引诱剂是抑制松墨天牛种群数量的无公害调控有效方式之一。本研究通过在中国浙江富阳的林间试验测定了 6 种小蠹类引诱剂与 1 种天牛引诱剂不同组合联用对松墨天牛成虫以及其他蛀干害虫的诱捕效果。结果表明: 横坑切梢小蠹 *Tomicus minor* 引诱剂 3-carene-10-ol、云杉八齿小蠹 *Ips typographus* 引诱剂 2-methyl-3-buten-2-ol、欧洲榆小蠹 *Scolytus multistriatus* 引诱剂 4-methyl-3-heptanol 和纵坑切梢小蠹 *T. piniperda* 引诱剂 verbenol 分别与松墨天牛引诱剂联用后, 对松墨天牛的引诱效果无显著性差异 ($P < 0.05$)。西部松大小蠹 *Dendroctonus brevicomis* 引诱剂 exo-brevicommin 或黄杉大小蠹 *D. pseudotsugae* 引诱剂 1-methylcyclohex-2-en-1-ol 与松墨天牛引诱剂联用后对松墨天牛的诱捕效果有减弱的趋势。另外, 与单独使用中国天牛引诱剂相比, 小蠹类引诱剂与其联用后在诱捕其他蛀干害虫的种类和个体数量上均有所减少。

关键词: 松墨天牛; 小蠹虫; 引诱剂; 诱捕; 蛀干甲虫

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